Integration of Risk Assessment
With a State Dam Safety Program

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Colorado Dam Safety Program

- Program Mission
  - Prevent loss of life and property damage,
  - Determine the safe water storage level
  - Protect the state's water supplies,
  - Prevent the failure of dams
  - Within the resources available.

Statutory Authorities

- 37-87-105-Approval of Plans for Reservoir-Notice of Modification
  - Rules and Regulations
  - New, Construction, Alteration, Modification, Repair and Enlargement-general maintenance excluded
- 37-87-107- Safety Inspections-Amount of Water to be Stored
  - Inspections
  - Safe Water Storage Level

Authorities Continued

- 37-87-108.5 - Emergency Actions
- 37-87-109 - Complaints that Reservoir is Unsafe
- 37-87-114 - Penalty - Disposition of Fines
- 37-87-114.4 - Annual Report
- 37-87-114.5 - Applicability of Provisions - Exemptions (Erosion Control Dams, Livestock Water Tanks)

Reservoir Storage

	Current Storage 1840 Dams	Restricted Storage* Total a-f (#dams)
Division 1	1,787,810 a-f	33,900 (99)
Division 2	893,544 a-f	89,200 (31)
Division 3	297,261 a-f	9,700 (3)
Division 4	1,447,948 a-f	4,200 (28)
Division 5	1,166,040 a-f	2,990 (19)
Division 6	165,387 a-f	1,400 (11)
Division 7	665,356 a-f	1,460 (7)
Total	6,423,345 a-f	142,850 (198)

*Safe Storage Level Determined by Inspection and Other Information Affecting the Safety of Each Dam (37-87-107)

Dam Incidents

- Total number of incidents (1990-2001) 32
  - Class 1-18; Class 2 - 9; Class 3 - 5
- Summary by year
  - 1990 - 1 1991 - 0 1992 - 2
    1993 - 1 1994 - 1 1995 - 2
    1996 - 2 1997 - 3 1998 - 2
    1999 - 9 2000 – 2 2001 - 7
- The greatest risk is most often associated with operational or static load conditions: seepage and erosion

Change Agents

- Ageing Infrastructure (and Staff)
- Change in Storage and Operation
- High Level of Experience and Knowledge
- Budget

Risk Assessment

- Additional Tool in the Assessment of the Safe Storage Level and Resource Protection
- Advanced Practice in Assessment of Dams for Safety and Reduction of Risk
- Full Spectrum of Analysis and Implementation-Not a One-Size Fits All
- Improved Public Safety and Resource Use

Risk Assessment Goal

- **Understand What Actions Should Be Taken To Reduce the Likelihood of Dam Failure and To Lessen the Adverse Consequences if a Failure Were To Occur**

- **A better position to advise owners on what action(s) should be done to reduce risk of failure and improved justification to impose storage restrictions if such action(s) are not taken.**

Risk Assessment

- Risk - Based Profiling
- Failure Mode and Consequences Evaluation
- Risk Management

Risk-Based Profiling System

- A means for ranking the dams in an inventory according to failure likelihood and/or exposure to risk in a consistent manner.
- A risk-based tool that is consistent with the risk equation (probability of load x probability of adverse response given load x magnitude of consequence). Consequences can be economic, life loss, social or environmental.

Risk Profiling Implementation

- Adapt a Risk Profiling System patterned on the USBR program. Revise some of worksheets to fit knowledge and experience of State Engineer's staff and simplify some aspects (especially life loss portion).

Dam Safety Risk Based Profile System - **Worksheet A - Static Response Factor for Embankment Dams**

Outlet works (76 points) - Only score dams with outlet works through embankment. Do not score dams with outlet works through a tunnel or no outlet works.	**Reservoir filling history (75 points)** Note: hydraulic height = streambed to maximum controllable water surface)	**Seepage and Deformation (79 points)**
Check all that apply: ❑ No downstream filters or filter zone around conduit. ❑ Outlet conduit located in deep (greater than height of conduit) and narrow trench (cutslopes steeper than 2:1) in soil or rock, particularly with vertical or irregular sides or close to abutment slope. ❑ Outlet pipe of material prone to corrosion in badly deteriorated condition or of unknown condition; masonry construction. ❑ Poor conduit geometry such as overhangs; poor haunch support; seepage cutoff collars or other features that make compaction of the backfill around the conduit difficult; poorly compacted backfill ❑ Open cracks in the outlet conduit, open joints, weep holes, seepage from cracks/joints into conduit. ❑ Conduit founded on soil or highly compressive/expansive rock.	Identify which one applies: 75 points — Reservoir never filled to 50 % of hydraulic height 50 points — Reservoir filled 50 % to 75 % of hydraulic height 25 points — Reservoir filled 75 % to 90 % of hydraulic height 10 points — Reservoir filled 90 % to 95 % of hydraulic height 5 points — Reservoir filled 95% to 100% of hydraulic height 0 points — Reservoir ≥ 100% of hydraulic height	Check all that apply: Critical: ❑ Seepage carrying fines (excluding benign sandboils). ❑ Seepage increasing at same reservoir elevation. Significant: ❑ Large amount of seepage. ❑ Slope movement (longitudinal cracking, offsets). ❑ Sinkholes, depressions. ❑ Poor toe drains (potential conduit for piping). ❑ Poor conditions at crest [badly eroded crest area, trees/rodent holes within 10' (vert.) of crest, serious displacements, sinkholes, transverse cracking > 1 ft. depth]. ❑ Abnormally high artesian pressures beneath D/S foundation area. ❑ Inadequate slope protection
Scoring: ___ items x 4 pts. = _____ (19 pts. max) Multiply this by type factor (see reverse) to obtain Outlet Works Score (max. score = 76)		Scoring: 79 points — Either of the Critical items 40 points — Five Significant items 30 points — Four Significant items 20 points — Three Significant items 10 points — Two Significant item 5 points — One Significant item
Outlet Works Score: _____	Reservoir Filling Score: _____	Seepage and Deformation Score: _____

Failure Mode and Consequence Evaluations

- A thorough review of the engineering data, operations, performance history and historic record of design and construction as well as the information related to consequences and planned emergency action on a dam by a team of persons in order to develop an understanding of the most significant failure modes / consequences / risk reductions with respect to dam safety.

- FMCE is a subset of risk analysis, but is simplified by qualitatively, rather than quantitatively, estimating the likelihood of adverse consequences from loads on dams, (hydrologic, static, and seismic). It includes a comprehensive review of the engineering data, operation, performance history, and record of design and construction, as well as information related to the consequences of failure and planned emergency procedures, by a team of experts in dam safety.

Why is this a good thing to do?

- A form of Failure Mode Evaluation linked with inspection to focus efforts on the most significant risk issues at each dam.
- Document Failure Modes determined on each dam in order to transfer knowledge to future inspectors (Information and institutional knowledge transfer and transition planning. Knowledge gained through such comprehensive efforts would be valuable to retain for future evaluations).

Key Components

- Physical Aspects: X-section, slope, crest width, etc
- O & M : water operations, visual observations and maintenance
- Outlet Condition and Configuration
- Seepage: Type, Location, Quantity, Monitoring
- Population at Risk: Warning system, EAP/EPP

Risk Management

- Key Risk Reduction Actions
- Resource Management
  - staff, funding, and priorities
  - Observation, monitoring, EAP and modification.
  - Focus on action resulting in the greatest reduction of risk
- Facility Improvement
  - Public Safety
  - Resource Use

Risk Assessment

- Risk - Based Profiling
  - A means for ranking the dams in an inventory according to failure likelihood and/or exposure to risk consistent with the risk equation
- Failure Mode and Consequences Evaluation
  - understanding of the most significant failure modes and consequences with respect to a specific dam
- Risk Management
  - Action and decisions to reduce risk and consequences of failure

Implementation

- Implement the Failure Mode and Consequence Evaluation Procedure and a Risk -Based Profiling system to give the State Dam Safety Program Engineers additional tools to accomplish program goals.
- A pilot project approach – develop written examples to illustrate process and gain experience.
- Identify the top ten (or so) dams with respect to risk – to illustrate the value to owners and others.

Plan for Implementation

- Designate a process driver or drivers (champion) among the Engineers for each of the trial processes for the purpose of facilitating implementation and coordinate future revisions.
- Assess of Pilot Project in March 2002

Pilot Program

- Train our staff and evaluate Failure Modes and Consequence Evaluations (FMCE).
- Simultaneously began an evaluation of the US Bureau of Reclamation's Risk Based Profiling System (RBPS). It is a an indexing method for ranking dams in accordance with weighted failure modes and consequences.

- Implement some form of Failure Mode and Consequence Evaluation Process geared to needs and resource capabilities of State. Specific ideas included:
  - Review team made up of (Principal Engineer +owner), (WC + Dam Safety Engineer + Division Engineer + Owner /Consultant), (previous + Denver Office)
  - Set up a team for week to do several dams in Division
  - Identify dams to be completed this year (random, 4 worst, a mix)
  - Use a facilitator in the pilot to give State personnel training and experience

Current Status

- Completed 8 Failure Modes and Consequences Evaluations
- Contract executed for Risk Profiling Tool
- Informal implementation of Risk Profiling to address resource limitations

Questions?

The End